Pilot Test of Nutrient Removal by Large-Scale Drip Dispersal of Tertiary-Treated Effluent, Southern Vermont

Craig Heindel, C.P.G.
Senior Hydrogeologist,
Waite-Heindel
Envir. Mgmt.
Burlington, VT

2020 NEWEA
Annual Conference
Boston, MA; Jan. 27, 2020

- # Proposed Residential
and Commercial Development
at Bromley Ski Area, Peru, VT

WH WAITE HEINDEL
Environmental Management

- **Proposed Development at Bromley Ski Area;**

- **Soil-based Wastewater Disposal of 80,000 gpd**

WAITE HEINDEL
Environmental Management

- **Proposed Development at Bromley Ski Area;**
  - **Soil-based Wastewater Disposal, 80,000 gpd;**

- **Impacts on In-stream Nutrients are limited by VT regulations;**

- **Proposed Development at Bromley Ski Area;**
- **Soil-based Wastewater Disposal, 80,000 gpd;**
- **Impacts on In-stream Nutrients are limited by VT regulations;**

- **Tertiary Treatment.**

WAITE
HEINDEL
Environmental Management

DESIGN PARAMETERS:

- **Wastewater Disposal Volume: about 80,000 gpd;**
- **Wastewater Treatment: Tertiary;**
- **Treated Wastewater Disposal Method: Soil-based disposal.**

➢ **These design parameters trigger Vermont's Indirect Discharge Regulations, which require field verification of nutrient removal by soils at disposal area.**

PURPOSE OF PILOT STUDY: To PROVIDE ONE PARAMETER in MASS-BALANCE CALCULATION of PREDICTED NUTRIENT IMPACT on RECEIVING STREAM:

§14-912   Determining Compliance With Aquatic Permitting Criteria

(a)   To determine compliance with the Aquatic Permitting Criteria, a mass balance equation shall be used. The resulting in-stream concentration calculated with the mass balance equation must be less than or equal to the Aquatic Permitting Criterion for each parameter to demonstrate compliance. The following mass balance equation shall be used for calculating the resulting in-stream concentration:

$$\frac{[(E_c) \times (E_q) + (D_c) \times (D_q)]}{(E_q + D_q)} = \text{Resulting in-stream concentration}$$

Where: E_c = Existing in-stream receiving water concentration

E_q = Appropriate stream flow at point of compliance and for annual or seasonal release rate.

D_c = In-ground effluent concentration (5% exc), based on site specific testing.

D_q = Proposed discharge flow (i.e. maximum design capacity) .

**From VT Indirect Discharge Rules
[WW Disposal > 6,500 gpd]**

7

WH WAITE HEINDEL

PARAMETER in MASS-BALANCE CALCULATION:

"IN-GROUND EFFLUENT CONCENTRATION"
[Groundwater Concentration beneath Disposal Area],
based on site-specific testing

§14-912   Determining Compliance With Aquatic Permitting Criteria

(a)   To determine compliance with the Aquatic Permitting Criteria, a mass balance equation shall be used. The resulting in-stream concentration calculated with the mass balance equation must be less than or equal to the Aquatic Permitting Criterion for each parameter to demonstrate compliance. The following mass balance equation shall be used for calculating the resulting in-stream concentration:

$$\frac{[(E_c) \times (E_q) + (D_c) \times (D_q)]}{(E_q + D_q)} = \text{Resulting in-stream concentration}$$

Where: E_c = Existing in-stream receiving water concentration

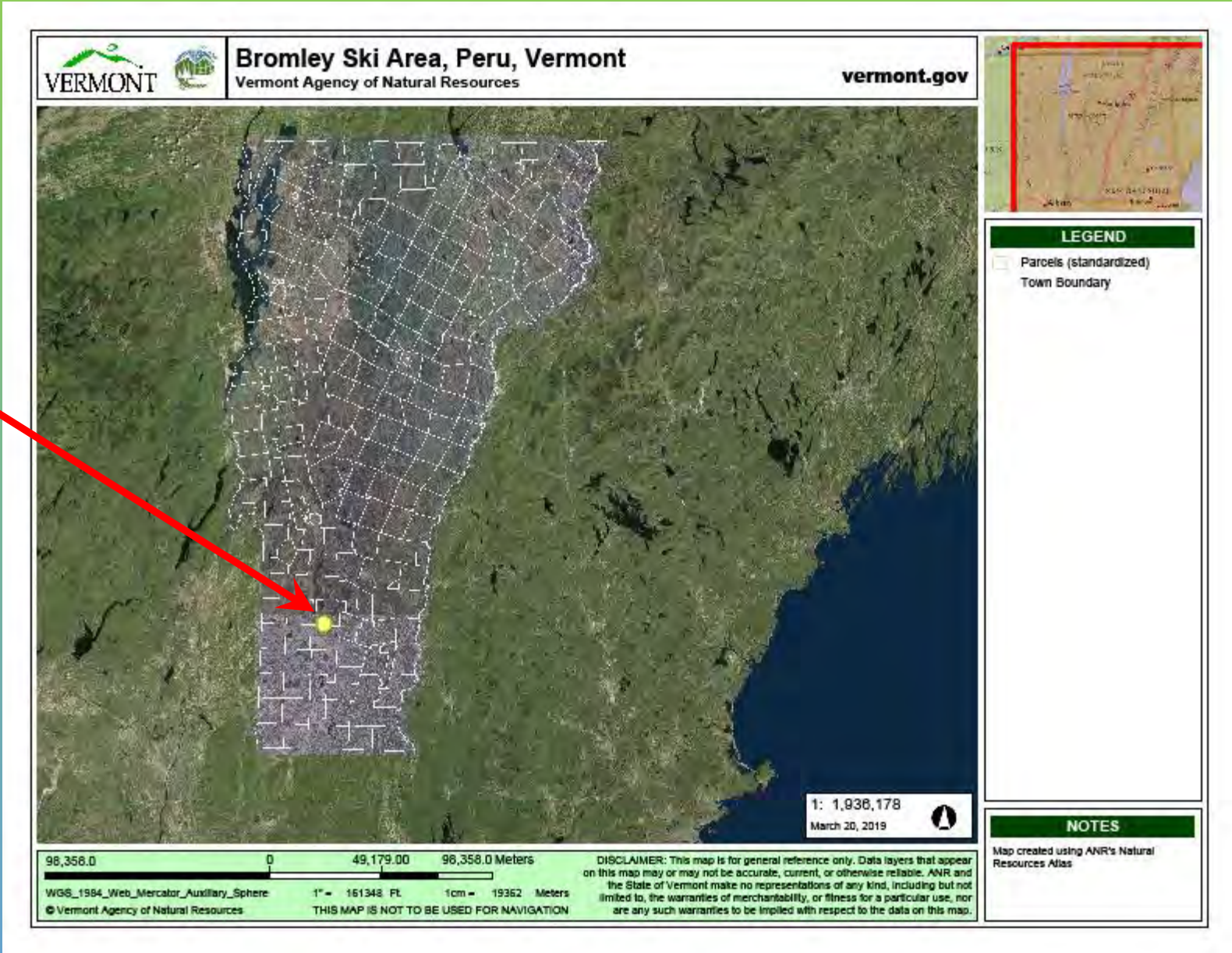E_q = Appropriate stream flow at point of compliance and for annual or seasonal release rate.

D_c = In-ground effluent concentration (5% exc), based on site specific testing.

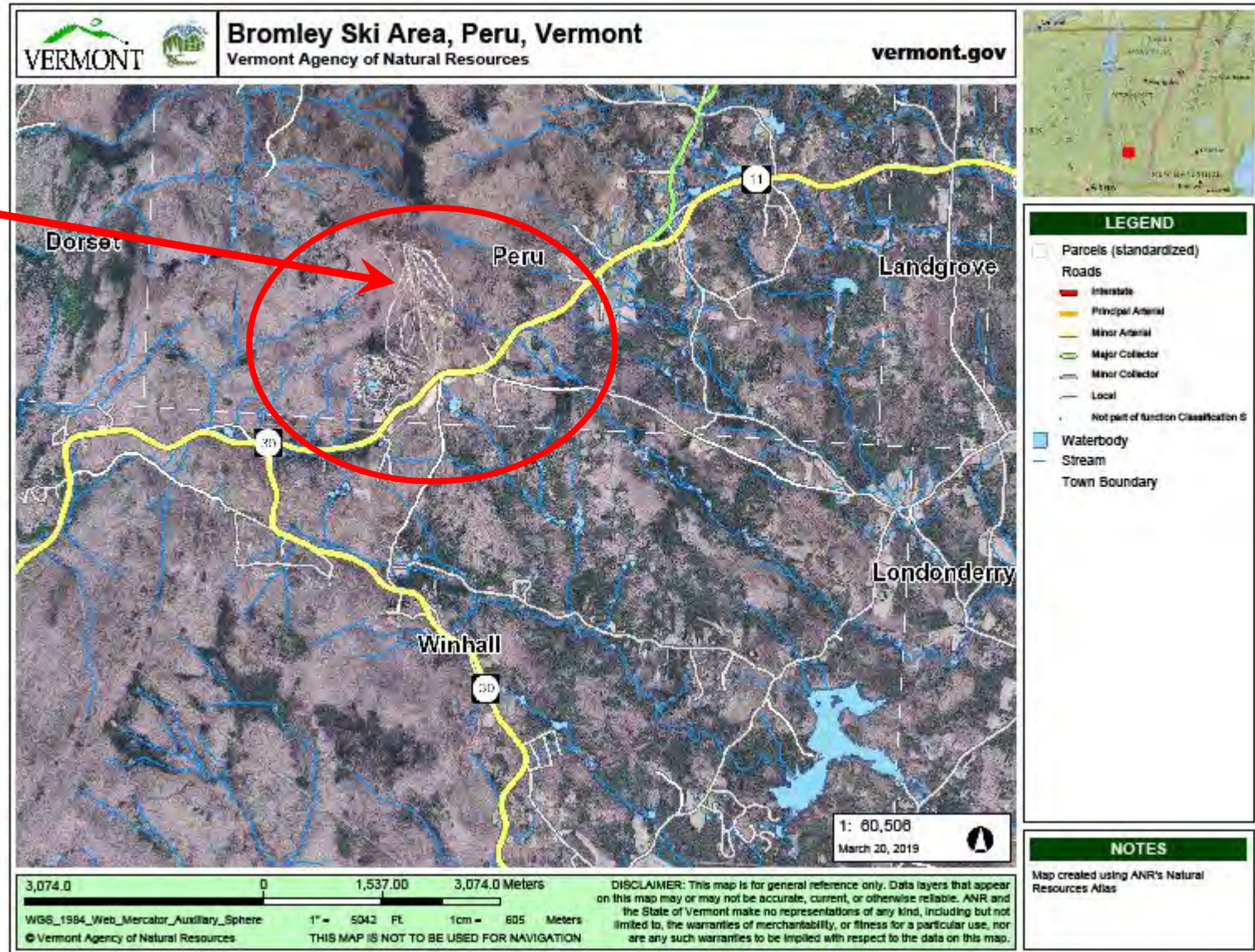D_q = Proposed discharge flow (i.e. maximum design capacity).

8

WAITE HEINDEL

Pilot Test, Nutrient Removal by Drip Dispersal
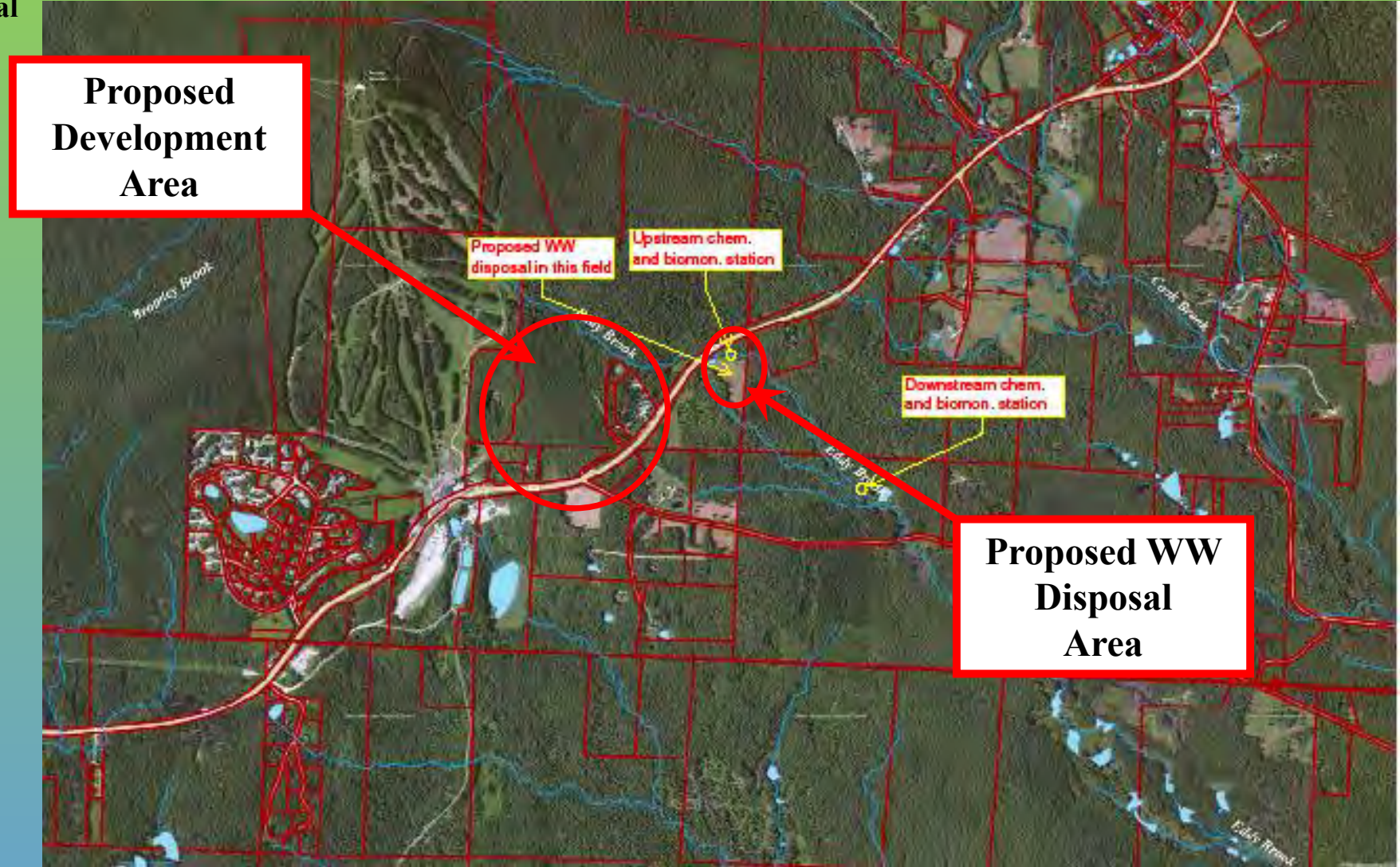
Bromley Ski Area, Peru, VT

9

Pilot Test, Nutrient Removal by Drip Dispersal

Bromley Ski Area, Peru, VT

Pilot Test, Nutrient Removal by Drip Dispersal
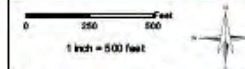

11

**Pilot Test, Nutrient Removal
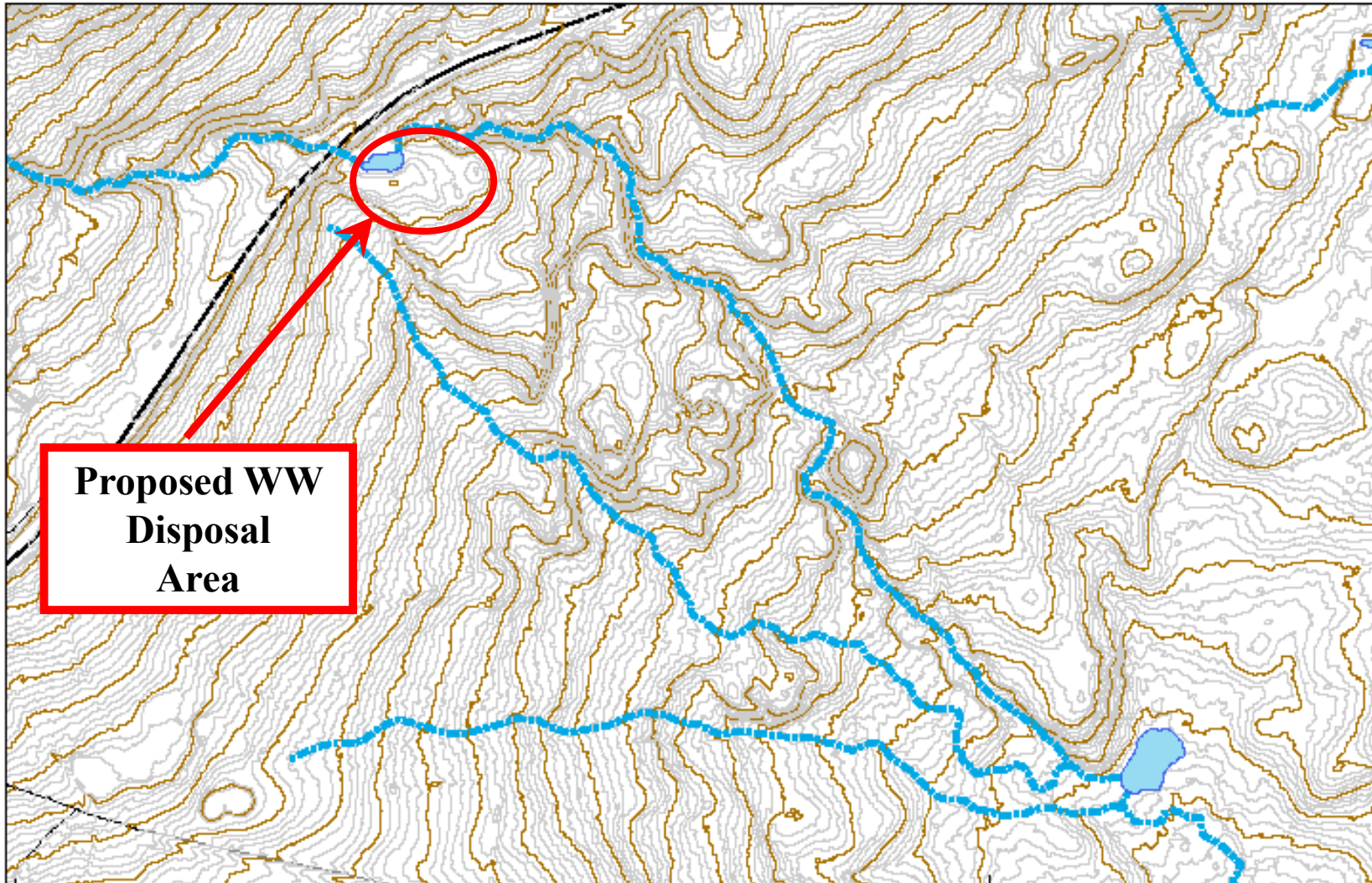by Drip Dispersal**

**Proposed WW
Disposal
Area**

12

Proposed WW Disposal Area

Dashed Blue = "Stream", from VCGI Hydrology database.

Topography: 2-ft. Contour Interval LIDAR, from VCGI

Proposed Wastewater Disposal Area;
Bromley Best Farm

1 inch = 400 feet

0   400   800   Feet
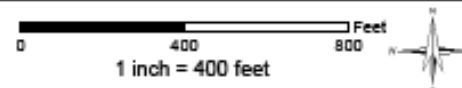
March 7, 2017
Map produced by: C. Heindel
BROMLEY\Best Farm WW Area\WHEM Maps\Untitled.mxd

Waite - Heindel
Environmental Management

WAITE
HEINDEL
Environmental Management

13

Pilot Test, Nutrient Removal by Drip Dispersal

Favorable Area for Drip Dispersal: 50,000 to 60,000 sq.ft.

25-ft. setback from Top of Bank

MOST FAVORABLE AREA FOR DRIP DISPERSAL

Top of Bank

OPEN FIELD

15
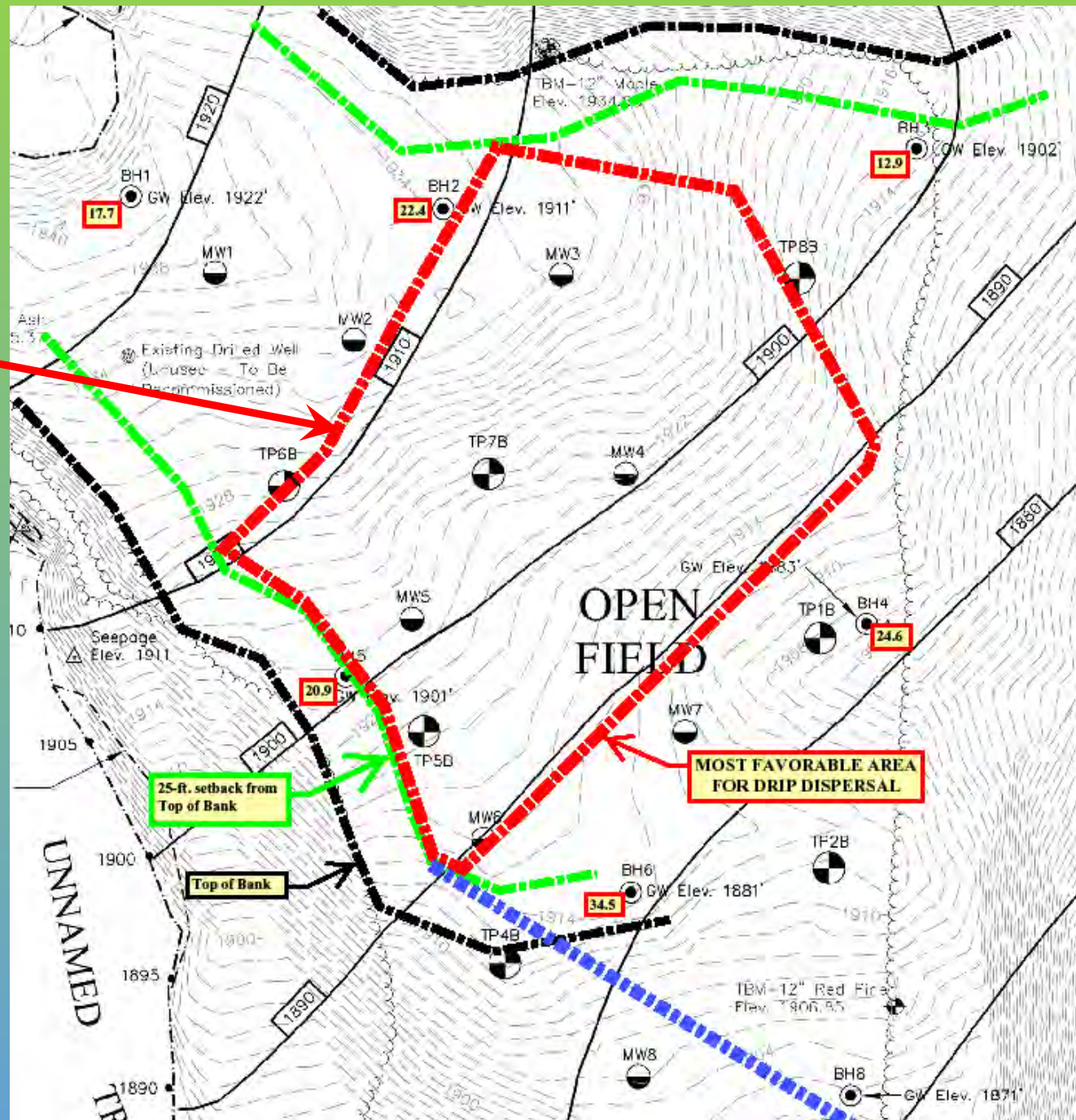
**NRCS Soil Series:
Peru
Fine Sandy Loam**

[parent material = loamy lodgement till]
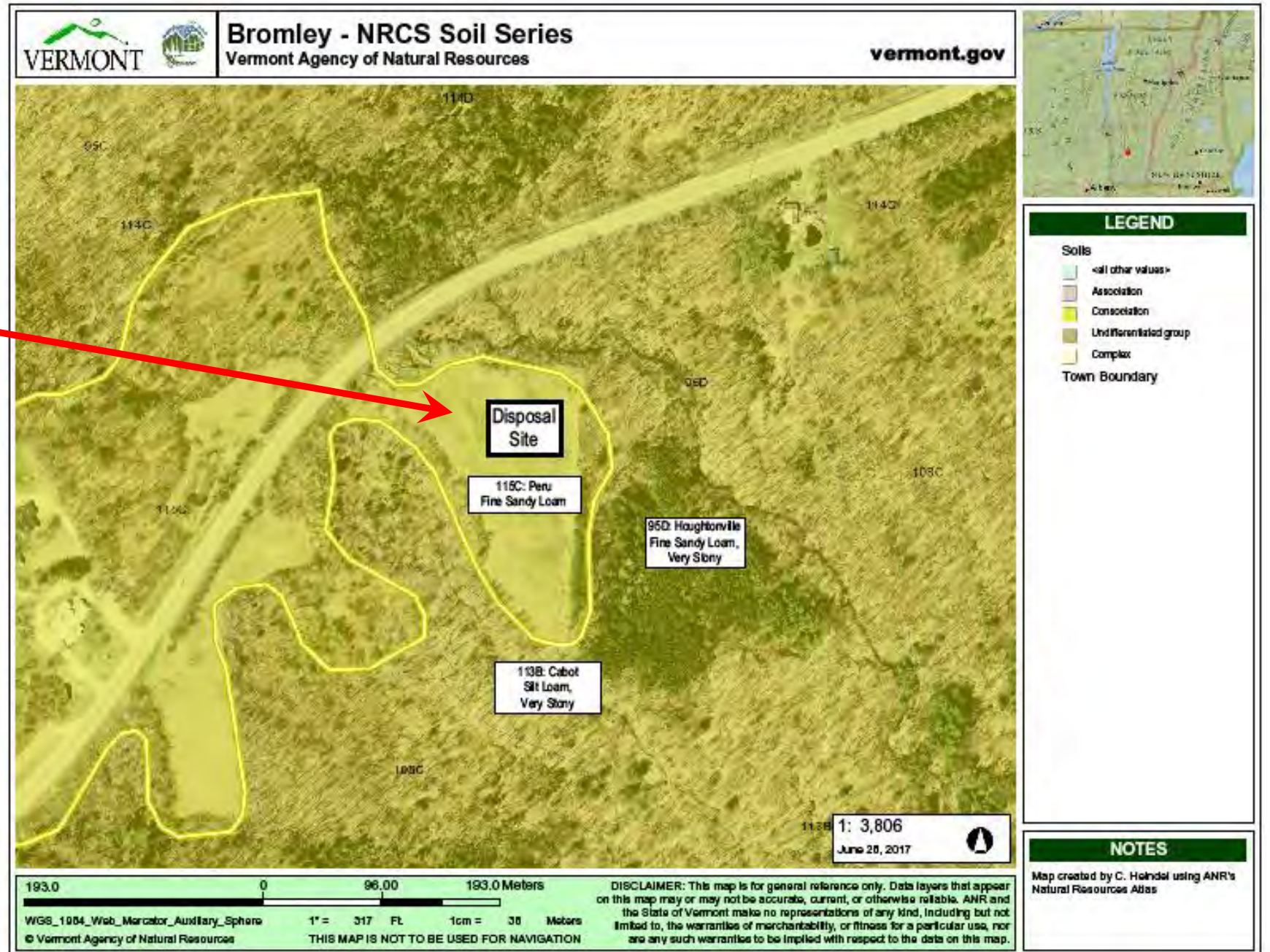
ON-SITE SOILS:

**Sandy Loam,
over
15 to 25 feet of
Unsaturated
Sands & Gravels**

[glacio-fluvial deposit]

WH WAITE HEINDEL

PILOT TEST PURPOSE:

Provide groundwater concentrations
of nutrients NO3 and TDP
down-gradient of disposal area
["in-ground effluent concentrations"]

for use in Mass-Balance Prediction
of Nutrient Impacts on Receiving Stream

WH WAITE HEINDEL

PILOT TEST DETAILS:

- **<u>Drip dispersal field</u>: 235 ft. x 11 ft., 4 dispersal pipes; application area: 2,515 sq.ft.**

PILOT TEST DETAILS:

- Drip dispersal field: 235 ft. x 11 ft., 4 dispersal pipes; application area: 2,515 sq.ft.

- **Test Effluent: Start with wastewater effluent from Bromley WWTP (secondary treatment);**

- **To roughly mimic Tertiary Treatment, dilute it with well water by approximately 1:4;**

- **To track the progress of pilot test, spike it with Bromide as tracer [Pool-grade Sodium Bromide, 2 oz. / 1,000 gals]**

EL
Environmental Management

PILOT TEST DETAILS:

- **Drip dispersal field**: 235 ft. x 11 ft., 4 dispersal pipes; application area: 2,515 sq.ft.

- **Test Effluent**: Wastewater effluent from Bromley WWTP (secondary treatment), diluted with well water by approximately 1:4, spiked with Bromide as tracer.

- **Application Rate of Test Effluent: 2.0 gpd/sq.ft.; 5,020 gpd for 119 days.**

WAITE HEINDEL
Environmental Management

<u>PILOT TEST DETAILS:</u>

- <u>**Drip dispersal field**</u>: 235 ft. x 11 ft., 4 dispersal pipes; application area: 2,515 sq.ft.

- <u>**Test Effluent**</u>: Wastewater effluent from Bromley WWTP (secondary treatment), diluted with well water by approximately 1:4, spiked with Bromide as tracer.

- <u>**Application Rate of Test Effluent**</u>: 2.0 gpd/sq.ft.; 5,020 gpd for 119 days.

- <u>**Down-gradient groundwater quality, depth**</u>: sampled from MW-BH-3, located 35 ft. downgradient.

- <u>**Up-gradient groundwater [for comparison]**</u>: MW-BH-2, located 180 ft. upgradient.

PILOT TEST DETAILS:

Drip dispersal field: 235 ft. x 11 ft., 4 dispersal pipes; application area: 2,515 sq.ft.

PILOT TEST, DRIP DISPERSAL FIELD:

PILOT TEST, DRIP DISPERSAL FIELD:

PILOT TEST, DRIP DISPERSAL FIELD:

PILOT TEST, DRIP DISPERSAL FIELD:

PILOT TEST, DRIP DISPERSAL FIELD:

Perc-Rite® Drip Dispersal System, distributed by Oakson, from American Manufacturing:
- *0.5-in. diameter*
- *Emitters located every 2 ft.*
- *Emitter discharge rate: 0.61 gal/hour, over wide pressure range.*

PILOT TEST, DRIP DISPERSAL FIELD:

PILOT TEST, DRIP DISPERSAL FIELD:

PILOT TEST, DRIP DISPERSAL FIELD:

PILOT TEST, DRIP DISPERSAL FIELD:

37
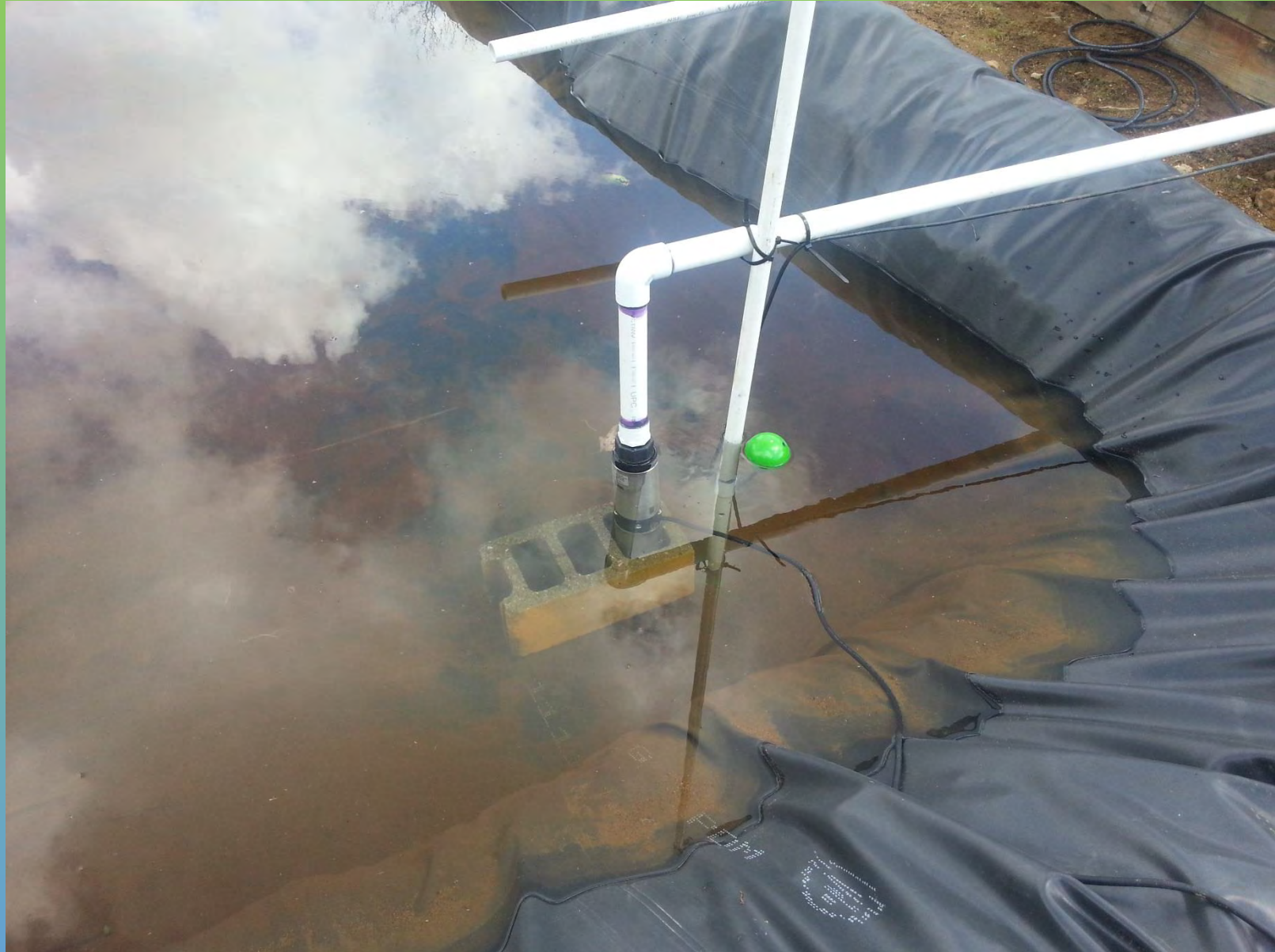
PILOT TEST: SPIKED EFFLUENT CHEMISTRY

Diluted & Spiked Effluent	Sample Date	BOD (5-Day) (mg/L)	Br (mg/L)	Chloride (mg/L)	NO3 as N (mg/L)	Nitrite as N (mg/L)	NH3 as N (mg/L)	TKN (mg/L)	Total N (mg/L)	TDP (mg/L)	TSS (mg/L)	Sodium (mg/L)	Cond. (mS/cm)	pH (s.u.)
	Mean	3.8	12	74	0.86	< 0.13	1.8	3.86	4.85	1.9	14	38	514	6.89
	Max	5	13	85	1.5	< 0.20	2.4	5.2	6.04	2.1	20	44	568	7.64
	Min	1.7	9.1	62	0.52	< 0.02	1.4	2.5	3.92	1.7	7	33	265	5.81

WAITE HEINDEL
Environmental Management

PILOT TEST, GRAPHS of RESULTS:

- Downgradient Groundwater Depths;
- Bromide Tracer
- Nitrate
- Total Dissolved Phosphorus

WAITE
HEINDEL
Environmental Management

In-Situ Pilot Test, Bromley Best Farm WW Disposal Area
Groundwater Depth in BH-3 (Downgradient)

15.8 ft. Initial [7/20/16]

PILOT TEST: GROUNDWATER DEPTHS, DOWN-GRADIENT

In-Situ Pilot Test, Bromley Best Farm WW Disposal Area
Groundwater Depth in BH-3 (Downgradient)

15.8 ft.
Initial
[7/20/16]

~ 12.7 ft.:
Induced groundwater mound
reaches equilibrium
in ~ 30 days

PILOT TEST: GROUNDWATER DEPTHS, DOWN-GRADIENT

In-Situ Pilot Test, Bromley Best Farm WW Disposal Area
Groundwater Depth in BH-3 (Downgradient)

In-Situ Pilot Test, Bromley Best Farm WW Disposal Area
Bromide and Groundwater Depth in BH-3 (Downgradient)

Initial
Br = ND < 0.10 mg/L
[7/20/16]

[Equilibrium of Induced Groundwater Mound]

Unfilled Symbol = Non-detected
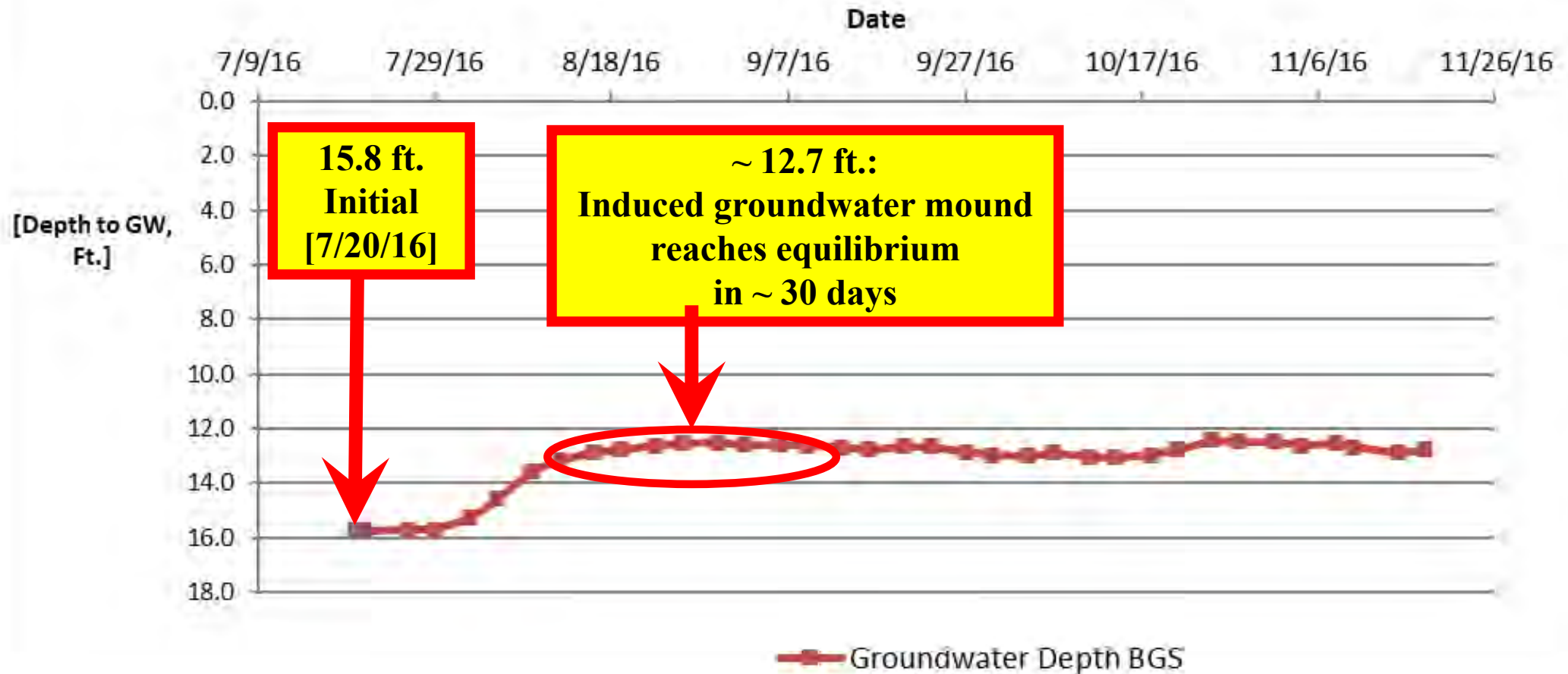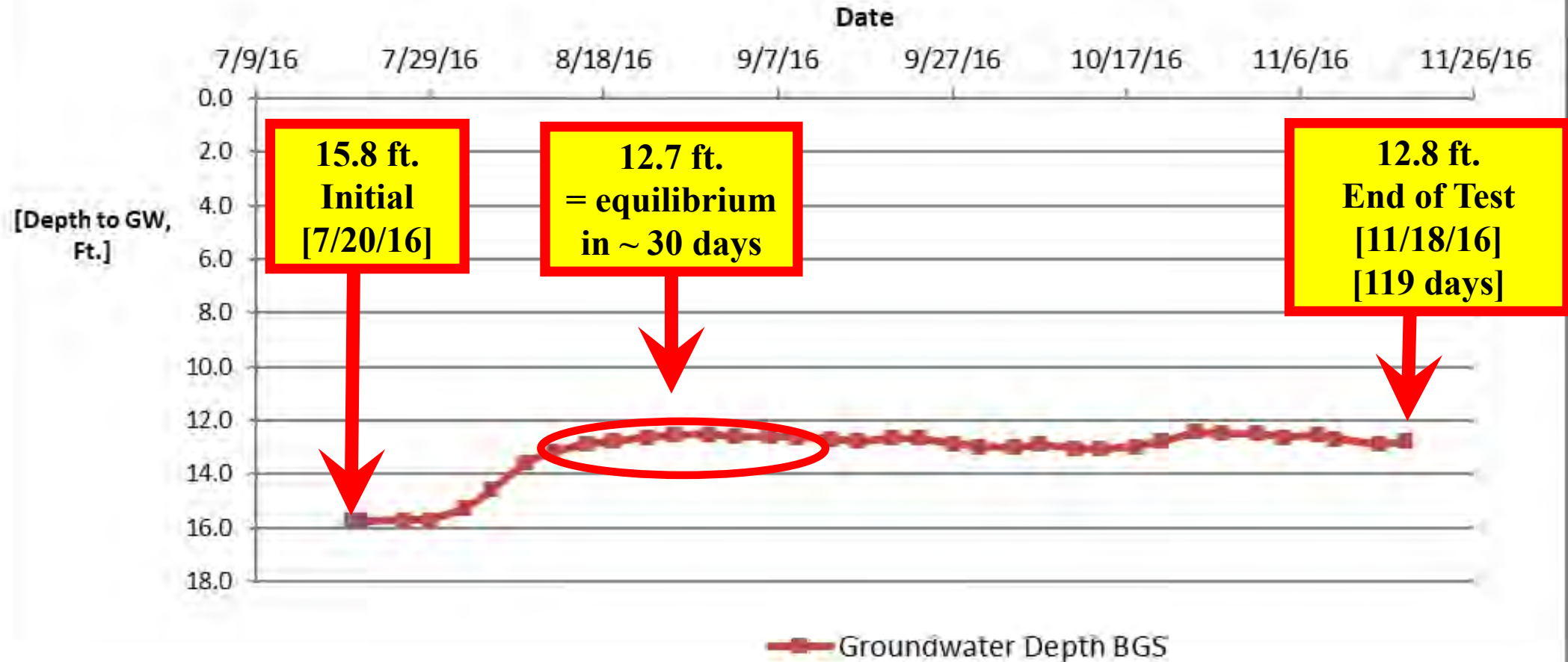
Bromide in BH-3

PILOT TEST: BROMIDE IN DOWN-GRADIENT GROUNDWATER

In-Situ Pilot Test, Bromley Best Farm WW Disposal Area
Bromide and Groundwater Depth in BH-3 (Downgradient)

Equilibrium Br = 9.8 mg/L [Nov. 10- 18, 2016] [111 – 119 days]

Initial Br = ND < 0.10 mg/L [7/20/16]

Unfilled Symbol = Non-detected

Bromide in BH-3

WAITE HEINDEL

PILOT TEST: NUTRIENTS IN DOWN-GRADIENT GROUNDWATER: NO3

In-Situ Pilot Test, Bromley Best Farm WW Disposal Area
Nitrate and Bromide in BH-3 (Downgradient)

Initial NITRATE:
Avg. = 0.24 mg/L

PILOT TEST: NUTRIENTS IN DOWN-GRADIENT GROUNDWATER: NO3

In-Situ Pilot Test, Bromley Best Farm WW Disposal Area
Nitrate and Bromide in BH-3 (Downgradient)

Initial NITRATE: Avg. = 0.24 mg/L

Final NITRATE: Avg. = 1.2 mg/L

PILOT TEST: NUTRIENTS IN DOWN-GRADIENT GROUNDWATER: TDP

In-Situ Pilot Test, Bromley Best Farm WW Disposal Area
Total Dissolved Phosphorus and Bromide in BH-3 (Downgradient)

Initial TDP:
Avg. = 0.017 mg/L
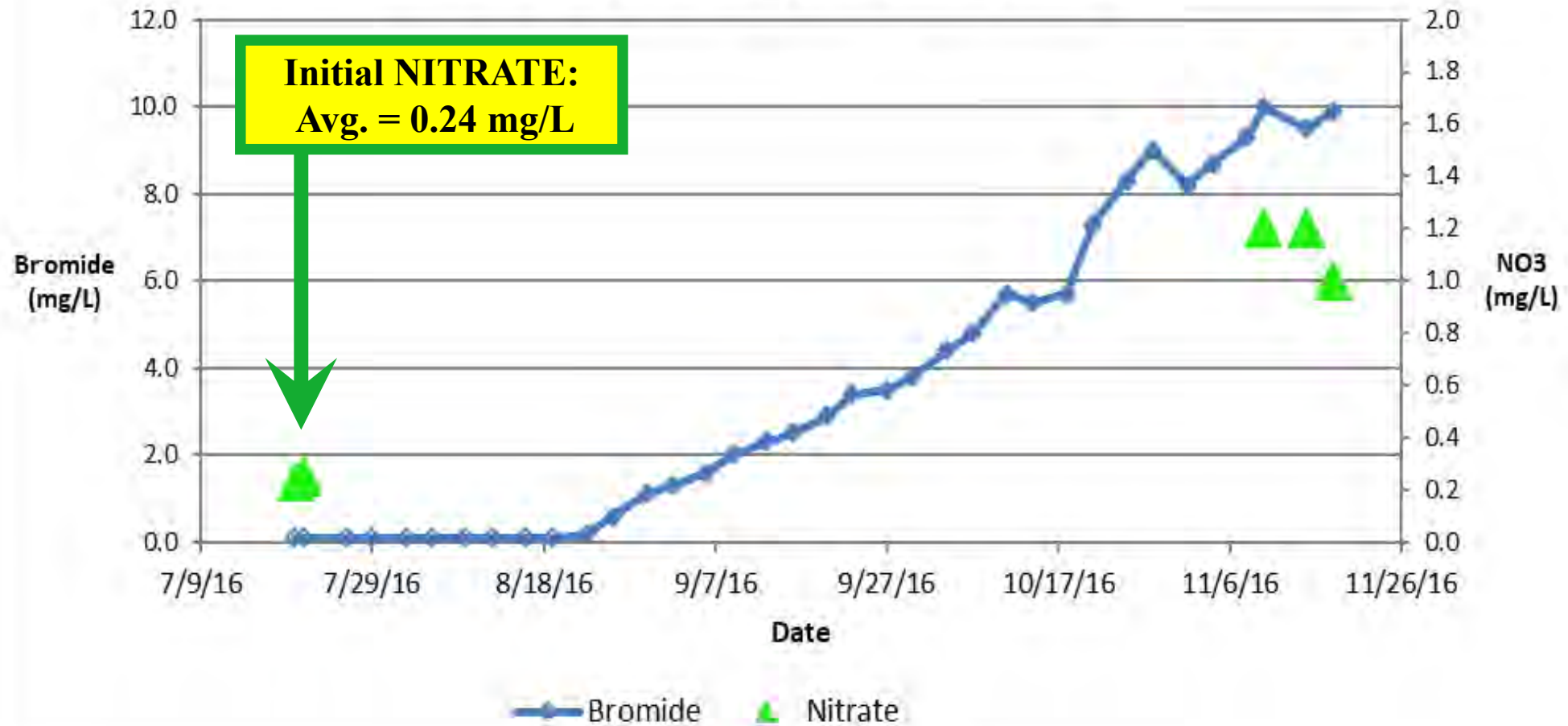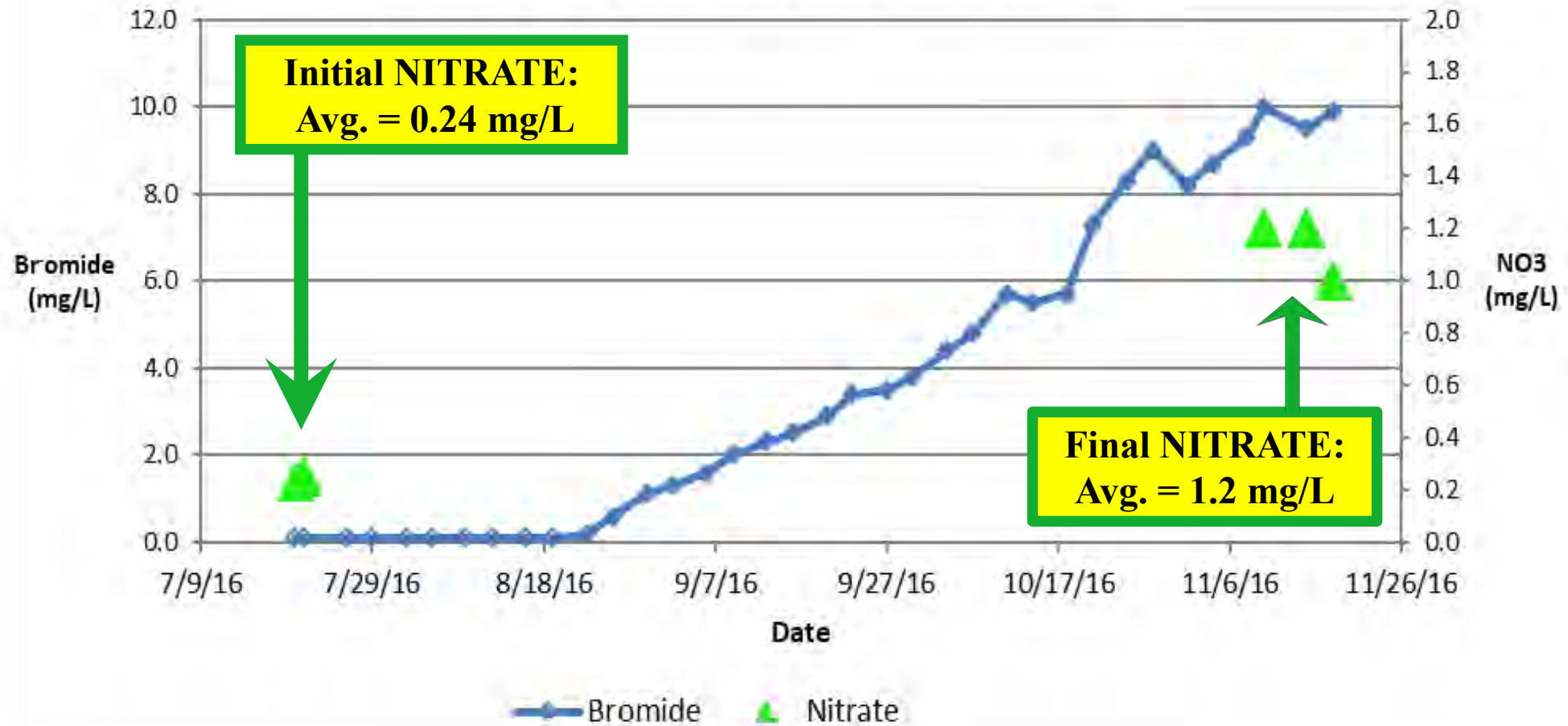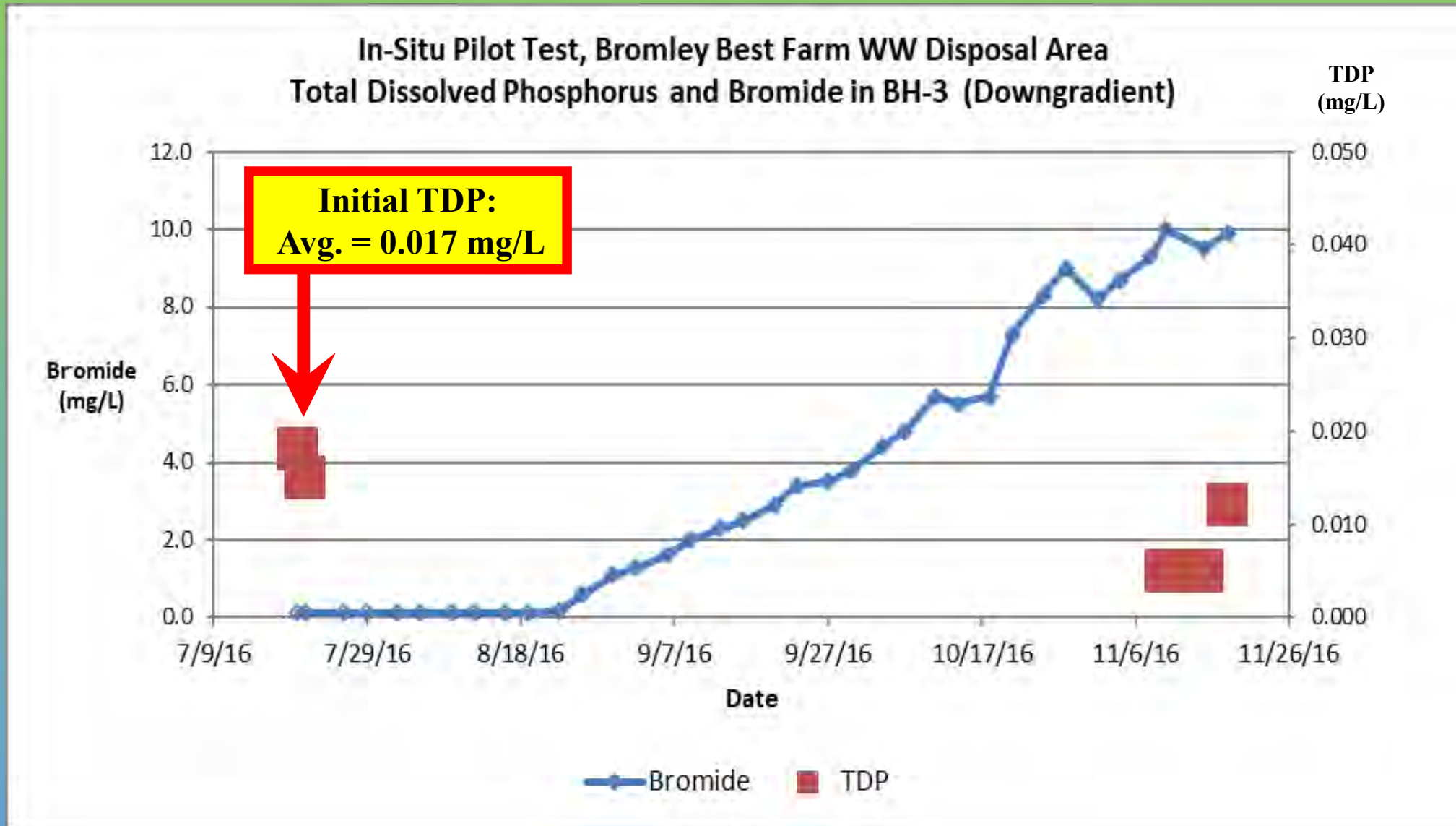
PILOT TEST: NUTRIENTS IN DOWN-GRADIENT GROUNDWATER: TDP
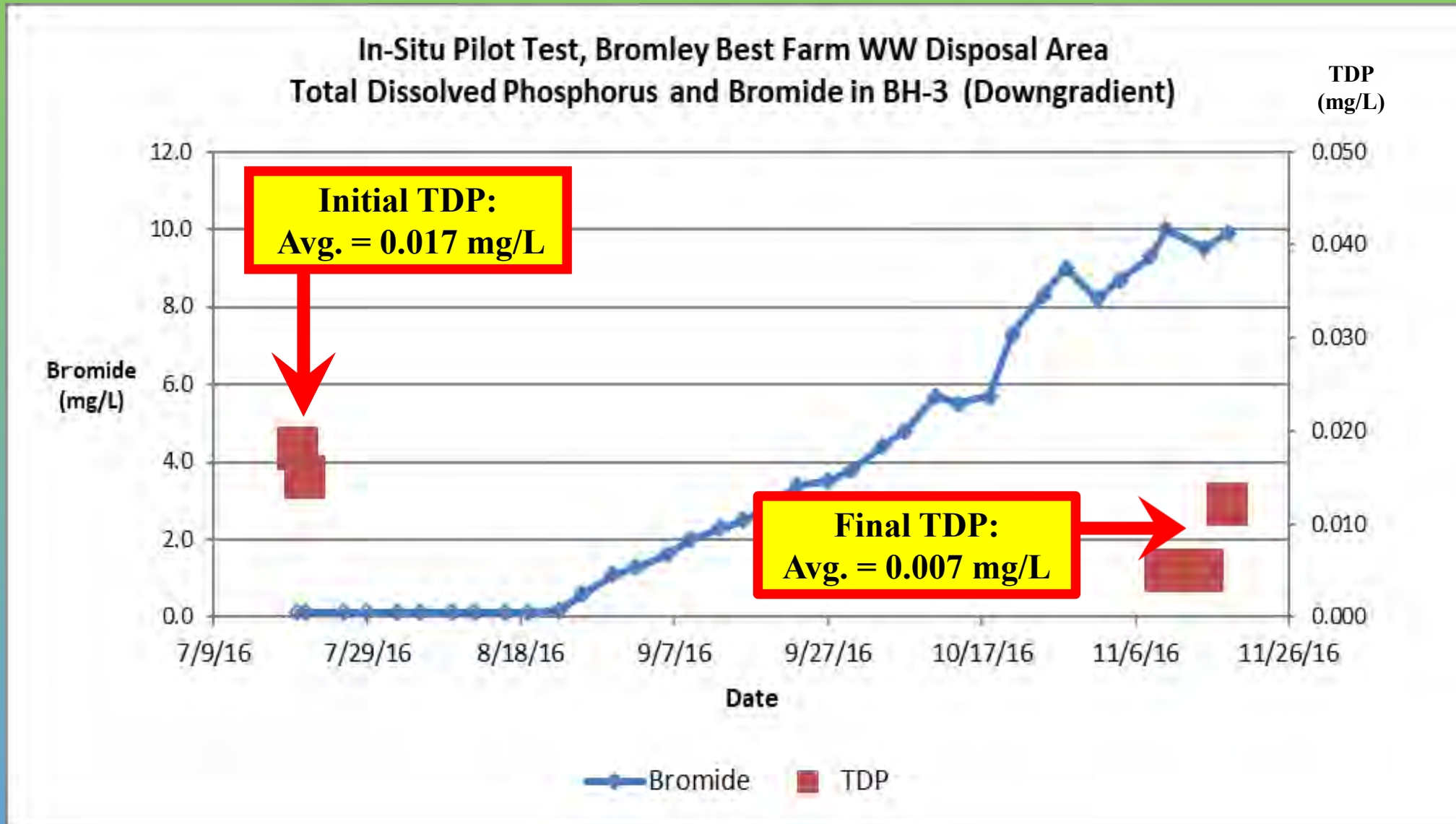
PILOT TEST RESULTS: NUTRIENTS IN DOWN-GRADIENT GROUNDWATER

Sample Date	Bromide (mg/L)	Nitrate as N (mg/L)	TDP (mg/L)	Depth to Water (ft BGS)
7/20/2016	< 0.10	0.23	0.018	15.75
7/21/2016	< 0.10	0.25	0.015	15.73
7/26/2016	< 0.10			15.72
11/8/2016	9.3			12.55
11/10/2016	10.0	1.2	< 0.005	12.69
11/15/2016	9.5	1.2	< 0.005	12.89
11/18/2016	9.9	1.0	0.012	12.76
Mean	3.7			
Max	10.0			
Min	0.1			

Final: 8-day equilibrium (11/10/2016, 11/15/2016, 11/18/2016)

Final NO3:
1.20 mg/L [max.]

= 4-fold increase over initial [0.24 Mg/L]

Final TDP:
0.007 mg/L [avg.]
0.012 mg/L [max.]

= decrease from initial [0.017 Mg/L]

BACK TO THE PURPOSE OF THE PILOT STUDY:
To predict nutrient impact on Receiving Stream.

Calculation Method: Mass-balance,
at Compliance Point in Eddy Brook:

§14-912   **Determining Compliance With Aquatic Permitting Criteria**

(a)   To determine compliance with the Aquatic Permitting Criteria, a mass balance equation shall be used. The resulting in-stream concentration calculated with the mass balance equation must be less than or equal to the Aquatic Permitting Criterion for each parameter to demonstrate compliance. The following mass balance equation shall be used for calculating the resulting in-stream concentration:

$$\frac{[(E_c) \times (E_q) + (D_c) \times (D_q)]}{(E_q + D_q)} = \text{Resulting in-stream concentration}$$

Where: E_c = Existing in-stream receiving water concentration
E_q = Appropriate stream flow at point of compliance and for annual or seasonal release rate.
D_c = In-ground effluent concentration (5% exc), based on site specific testing.
D_q = Proposed discharge flow (i.e. maximum design capacity) .

"In-ground Effluent" Concentration [Down-gradient Groundwater Conc.]

51

WAITE HEINDEL

Calculation Method: Mass-balance, at Compliance Point in Eddy Brook:

§14-912 Determining Compliance With Aquatic Permitting Criteria

(a) To determine compliance with the Aquatic Permitting Criteria, a mass balance equation shall be used. The resulting in-stream concentration calculated with the mass balance equation must be less than or equal to the Aquatic Permitting Criterion for each parameter to demonstrate compliance. The following mass balance equation shall be used for calculating the resulting in-stream concentration:

$$\frac{[(E_c) \times (E_q) + (D_c) \times (D_q)]}{(E_q + D_q)} = \text{Resulting in-stream concentration}$$

Where: E_c = Existing in-stream receiving water concentration
E_q = Appropriate stream flow at point of compliance and for annual or seasonal release rate.
D_c = In-ground effluent concentration (5% exc), based on site specific testing.
D_q = Proposed discharge flow (i.e. maximum design capacity).

[Down-gradient Groundwater Conc.]

Final "In-Ground Effluent" [Groundwater] Nutrient Concentrations:
➤ **NO3: 1.20 Mg/L;**
➤ **TDP: 0.012 Mg/L.**

52

WAITE HEINDEL

Calculation Method: Mass-balance, at Compliance Point in Eddy Brook:

$$\frac{[(E_c) \times (E_q) + (D_c) \times (D_q)]}{(E_q + D_q)} = \text{Resulting in-stream concentration}$$

- **Stream Concentrations [Ec]:**
  ~ **0.021 Mg/L TDP;**   ~ **0.243 Mg/L NO3.**

- **Streamflow [Eq] = 97,769 gpd [LMMF].**

- **"In-ground effluent" [Dc]:**
  ~ **0.012 Mg/L TDP;**   ~ **1.20 Mg/L NO3.**
  [max. of final 3 values];

- **Indirect Discharge Flow [Dq]: 80,000 gpd.**

53

WH WAITE HEINDEL

Mass-Balance Calculations & Results:

INPUT PARAMETERS:				Notes:
Chemical Name:	**TDP**			**Total Dissolved Phosphorus**
		units:		
Downgrad. GW Concentration:	0.012	mg/L		Maximum Value of 3 final Samples, Nov. 2016 in-situ pilot test
Upstream SW Concentration:	0.021	mg/L		Upper 95% C.V., from 2014 Eddy Brook Stream Sampling data
IDP Standard:	increase of 0.001	mg/L		per IDRs
Type of Discharge:	Annual			drip dispersal
Stream Name:	Eddy Brook			
LMMF:	97,769	gpd		0.445 mi^2 drainage area * 0.34 csm, converted to gpd
Disposal Rate:	80,000	gpd		
Dilution Ratio at LMMF:	**1.22**	to 1		
RESULTS:				
Stream Flow Volume at LMMF:	370,056	Liters		conversion [ltrs = gal * 3.785]
Spray Disposal Volume:	302,800	Liters		conversion [ltrs = gal * 3.785]
Mass in Stream:	7,660	mg		conc. X vol.
Mass in Groundwater:	3,634	mg		conc. X vol.
Total Downgradient Mass:	11,294	mg		sum of 2 masses
Total Downgradient Volume:	672,856	Liters		sum of 2 volumes

Predicted Downstream Surface Water Concentration, at LMMF:				
	TDP			
	0.0168	mg/L		[sum of masses] / [sum of vols]
Predicted Increase from Upstream to Downstream:				
	TDP			
	-0.0039	mg/L		**OK: < 0.001 mg/L increase**
	[decrease]			

WH WAITE HEINDEL

Mass-Balance Calculations & Results:

INPUT PARAMETERS:				Notes:
Chemical Name:	**NO3**			**Nitrate**
			units:	
Downgrad. GW Concentration:	1.20		mg/L	Maximum Value of 3 final Samples, Nov. 2016 in-situ pilot test
Upstream SW Concentration:	0.243		mg/L	Upper 95% C.V., from 2014 Eddy Brook Stream Sampling data
IDP Standard:	2.0		mg/L	per IDRs
Type of Discharge:	Annual			drip dispersal
Stream Name:	Eddy Brook			
LMMF:	97,769		gpd	0.445 mi^2 drainage area * 0.34 csm, converted to gpd
Disposal Rate:	80,000		gpd	
Dilution Ratio at LMMF:	**1.22**	to 1		
RESULTS:				
Stream Flow Volume at LMMF:	370,056		Liters	conversion [ltrs = gal * 3.785]
Spray Disposal Volume:	302,800		Liters	conversion [ltrs = gal * 3.785]
Mass in Stream:	89,887		mg	conc. X vol.
Mass in Groundwater:	363,360		mg	conc. X vol.
Total Downgradient Mass:	453,247		mg	sum of 2 masses
Total Downgradient Volume:	672,856		Liters	sum of 2 volumes

Predicted Downstream Surface Water Concentration, at LMMF:				
	NO3			
	0.674		mg/L	[sum of masses] / [sum of vols]
				OK: < 2.0 mg/L.
Predicted Increase from Upstream to Downstream:				
	NO3			
	0.431		mg/L	

WH WAITE HEINDEL

Mass-Balance Calculations & Results:

Predicted Downstream Surface Water Concentrations:					
			NO3:	**0.674**	mg/L	**OK: < 2.0 mg/L.**
			TDP:	**0.0168**	mg/L	

Predicted Increases from Upstream to Downstream:					
			NO3:	**0.431**	mg/L	
			TDP:	**-0.0039**	mg/L	**OK: < 0.001 mg/L increase**

WAITE
HEINDEL

Capacity Determination Letter" issued 6/13/2018
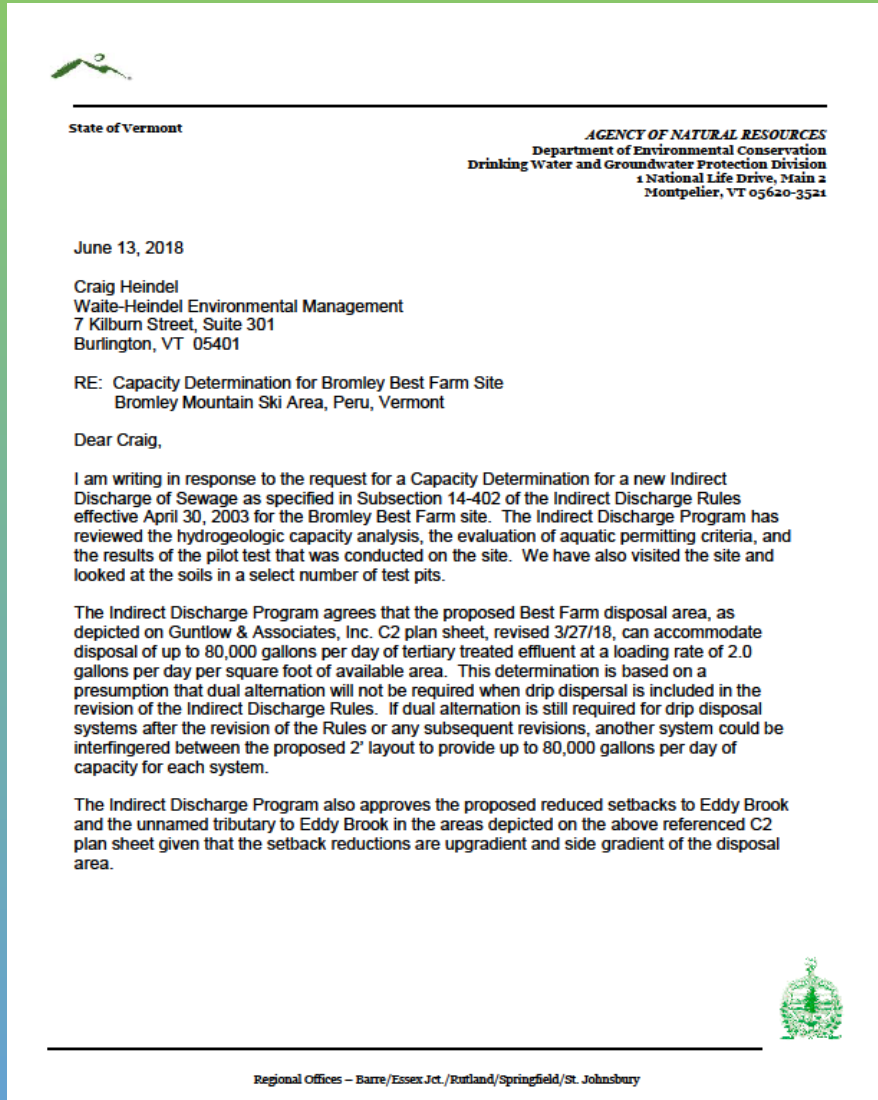
> **" … the proposed disposal area … can accommodate disposal of up to 80,000 gallons per day of tertiary treated effluent at a loading rate of 2.0 gallons per day per square foot …"**

57

**Pilot Test of Nutrient Removal by Large-Scale Drip Dispersal
of Tertiary-Treated Effluent, Southern Vermont**

SUMMARY:

1. 5,020 GPD of treated domestic WW effluent were applied to a pilot

   drip-dispersal field for 119 days in July through November 2016;

2. The pilot-test drip-dispersal field was 235 ft. x 10.7 ft. [2,515 sq.ft.]. Diluted secondary-treated wastewater spiked with Sodium Bromide as a tracer was applied at 2.0 gpd/sq.ft. via frequent small-volume timed doses;

WH WAITE
HEINDEL
Environmental Management

**Pilot Test of Nutrient Removal by Large-Scale Drip Dispersal
of Tertiary-Treated Effluent, Southern Vermont**

SUMMARY:

1. 5,020 GPD of treated domestic WW effluent were applied to a pilot

   drip-dispersal field for 119 days in July through November 2016;

2. The pilot-test drip-dispersal field was 235 ft. x 10.7 ft. [2,515 sq.ft.]. Diluted secondary-treated wastewater spiked with Sodium Bromide as a tracer was applied at 2.0 gpd/sq.ft. via frequent small-volume timed doses;

3. Soils at the drip-dispersal pipe depth [6" – 12"] are sandy loams; underlying parent material is fine-to-medium sands, with occasional lenses of gravelly coarse sand; substantial depths to groundwater.

WH WAITE HEINDEL
Environmental Management

Pilot Test of Nutrient Removal by Large-Scale Drip Dispersal of Tertiary-Treated Effluent, Southern Vermont

SUMMARY [cont.]:

4. Total Dissolved Phosphorus and Nitrate were analyzed in samples collected from downgradient groundwater and effluent.

Results of Pilot Test:

		Down-Gradient Groundwater	
	Effluent	Pre-Test	End of Test
Parameter:	Mg/L	Mg/L	Mg/L
TDP	1.9	0.017	0.012
NO3	0.86	0.24	1.2

WAITE HEINDEL
Environmental Management

Pilot Test of Nutrient Removal by Large-Scale Drip Dispersal of Tertiary-Treated Effluent, Southern Vermont

SUMMARY [cont.]:

5. The water table beneath the disposal field was initially at ~ 15 ft. below the drip-dispersal pipes. In response to the pilot test, groundwater rose by 2.9 ft. after ~ 30 days, then remained stable. So ~ 12 ft. of unsaturated soil was maintained below the drip-dispersal field for the final 80 days of the test.

WH WAITE HEINDEL
Environmental Management

Pilot Test of Nutrient Removal by Large-Scale Drip Dispersal of Tertiary-Treated Effluent, Southern Vermont

SUMMARY [cont.]:

6. The combination of drip-dispersal system with frequent small-volume timed doses of treated wastewater, plus sandy loam B-horizon and fine-to-medium sands below, plus deep unsaturated zone [12 to 15 ft.] provided more than 99% removal of Total Dissolved Phosphorus, and substantial conversion of Nitrogen to Nitrate.

WAITE HEINDEL
Environmental Management

Pilot Test of Nutrient Removal by Large-Scale Drip Dispersal of Tertiary-Treated Effluent, Southern Vermont

Special thanks to the team members who participated in conducting this pilot test:

- Bill Beideman, Phil Talbot, Pat Gordon – Bromley WWTP Operators;

- Bill Cairns, Michael Van Eyck – Bromley Ski Area management;

- Rob Sarmanian, Don Ottenheimer -- Oakson; Gloucester, MA;

- Vince Guntlow, P.E.; Guntlow & Associates, Williamstown, MA;

- Endyne Laboratories, Williston, VT; Lebanon, N.H.; Plattsburgh, N.Y.

WAITE HEINDEL Environmental Management

OAKSON

GUNTLOW & ASSOCIATES, INC.

Bromley Vermont's Sun Mountain

Pilot Test of Nutrient Removal by Large-Scale Drip Dispersal of Tertiary-Treated Effluent, Southern Vermont

Questions?

THANK YOU.

- Craig Heindel, C.P.G.; Senior Hydrogeologist, Waite-Heindel Environmental Management, Burlington, VT;
  cheindel@gmavt.net; www.waiteenv.com; 802-806-9400
- Rob Sarmanian, General Manager; Oakson; Gloucester, MA;
  rob@Oakson.com; www.Oakson.com; 978-282-1322
- Vince Guntlow, P.E.; Guntlow & Associates, Williamstown, MA;
  VinceG@guntlowassociates.com; www.guntlowassociates.com ; 413-458-2198;
- Bill Cairns, General Manager; Bromley Ski Area, Peru, VT;
  bc@bromley.com; www.bromley.com; 802-536-1686.

2019 NEIWPCC
Onsite Short Course

Extra Slides:
Data Table of
Nutrient Concentrations
In Downgradient Groundwater

PILOT TEST: NUTRIENTS IN DOWN-GRADIENT GROUNDWATER

Sample Date	Bromide (mg/L)	Nitrate as N (mg/L)	TDP (mg/L)	Depth to Water (ft BGS)
7/20/2016	< 0.10	0.23	0.018	15.75
7/21/2016	< 0.10	0.25	0.015	15.73
7/26/2016	< 0.10			15.72
11/8/2016	9.3			12.55
11/10/2016	10.0	1.2	< 0.005	12.69
11/15/2016	9.5	1.2	< 0.005	12.89
11/18/2016	9.9	1.0	0.012	12.76
Mean	3.7	0.8	0.011	13.22
Max	10.0	1.2	0.018	15.75
Min	0.1	0.2	0.005	12.43

Initial

WH WAITE HEINDEL
Environmental Management

PILOT TEST: NUTRIENTS IN DOWN-GRADIENT GROUNDWATER

Sample Date	Bromide (mg/L)	Nitrate as N (mg/L)	TDP (mg/L)	Depth to Water (ft BGS)
7/20/2016	< 0.10	0.23	0.018	15.75
7/21/2016	< 0.10	0.25	0.015	15.73
7/26/2016	< 0.10	Time Gap of 110 days Waiting for Br equilibrium		15.72
11/8/2016	9.3			12.55
11/10/2016	10.0	1.2	< 0.005	12.69
11/15/2016	9.5	1.2	< 0.005	12.89
11/18/2016	9.9	1.0	0.012	12.76
Mean	3.7	0.8	0.011	13.22
Max	10.0	1.2	0.018	15.75
Min	0.1	0.2	0.005	12.43

WAITE HEINDEL
Environmental Management

PILOT TEST: NUTRIENTS IN DOWN-GRADIENT GROUNDWATER

Sample Date	Bromide (mg/L)	Nitrate as N (mg/L)	TDP (mg/L)	Depth to Water (ft BGS)
7/20/2016	< 0.10	0.23	0.018	15.75
7/21/2016	< 0.10	0.25	0.015	15.73
7/26/2016	< 0.10			15.72
11/8/2016	9.3			12.55
11/10/2016	10.0	1.2	< 0.005	12.69
11/15/2016	9.5	1.2	< 0.005	12.89
11/18/2016	9.9	1.0	0.012	12.76
Mean	3.7	0.8	0.011	13.22
Max	10.0	1.2	0.018	15.75
Min	0.1	0.2	0.005	12.43

Final: 8-day equilibrium

68

WAITE HEINDEL
Environmental Management